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DEPARTMENT OF THE ARMY
Fort Detrick
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PHOTOELECTRIC DET... ... ... GRANULAR
SIZE DISTRIBUTION IN AN AEROSOL

1. Principle of the Method

The method is based on the measurement of light scat-
tering by the individual particles (1). The advantage lies in
the fact that a rapid determination of the number of particles
of a given granule size per unit volume of air is possible,
and also in the fact that all difficulties normally arising
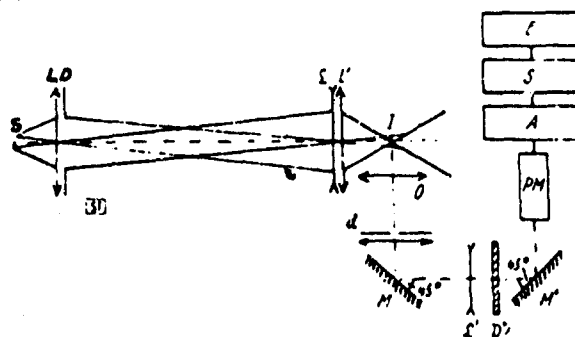when aerosols are placed on a microscope slide are eliminated.

Fig. 1 Principle of photoelectric particle size determination

The principle of the method is shown in Fig.1. The il-

lumination device consists of a source of very high brightness
S and a condenser with a large aperture which is constructed
in such a way that it uniformly illuminates the used portion
of a light field of objective O whose axis is vertical with
respect to that of the microscope. The particles which are to
be examined are drawn up by a correspondingly d: ected air cur-
rent and pass through the light field of the mi   oscope. The
light scattered by each particle is collected by objective O,
whereby the probability of two particles simultaneously migra-
ting through the light field and thereby being counted as one
particle of correspondingly larger diameter is extremely small.
This small probability is obtained by dilution of the air (for
instance in a Royco instrument for which a somewhat different
illumination device is used) and by reduction of the light
field of the microscope (1). The light intensity recorded by
the objective is led through an optical system to the cathode
of a photoamplifier. The signal emitted which has an amplitude
which is proportional to the light intensity is subsequently
correspondingly amplified and taken up in a multi-channel count-
ing mechanism which permits the mutual separation and simulta-
neous counting of the various impulse heights to be made.

Since the optical and electrical properties of the ins-
trument are known, the impulse height corresponding to a par-
ticle of given granule size and given composition can be cal-
culated. At present, the calibration of the instrument with a
known aerosol (spherical latex particles or stabilized water
droplets of known dimensions) is under way. However, it is e-
vident -- and this is the chief disadvantage of the method --
that the results obtained with this instrument, in spite of
all sharpness and accuracy of the method, depend on the dimen-
sions of the aerosol particles, as well as on their refractive
index and absorption coefficient. The smallest granule size
which can still be determined by this method ranges, at pre-
sent, from 0.3 to 0.6 μm; it is limited chiefly by the noise
of the photoamplifier and by stray light in the interior of
the instrument. An additional device with two photoamplifiers
in parallel is presently under construction; these two photo-
amplifiers should make possible a lowering of this range by
elimination of the noise and the stray light.

2. Application of the Method in the Determination of the Filler Efficiency (2)

The Royco instrument used requires a prior dilution of
the aerosol, but it is well suited for sampling behind a fil-
ter. An artificial aerosol with unobjectionably determined
properties was used for the studies, which was quite similar

to a natural aerosol. We do not wish to overestimate the dif-
ficulties in the choice of such an aerosol, which in our case
are reduced by the fact that we are able merely to determine
the granulometric and not the total degree of efficiency of a
filter, as it is the case with the classical methods. Conse-
quently, one must be satisfied in obtaining any easily reprodu-
cible artificial aerosol yielding at the Royco instrument a
particle size distribution which in the average corresponds
to the distribution of natural aerosols (smoking hemp wick im-
mersed in a solution of lactic acid, gum rubber , and po-
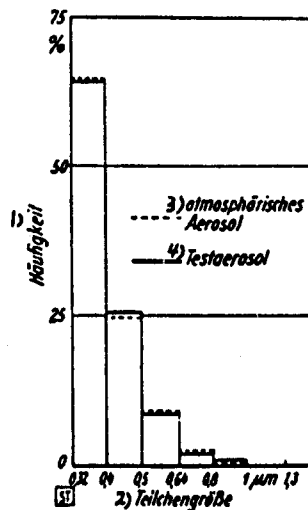tassium nitrate at a ratio of 2:2:5).

Fig. 2 Comparison of the particle dis-
tribution in the test aerosol and in
the natural, atmospheric aerosol
1 = frequency, 2 = particle size;
3 = atmospheric aerosol; 4 = test aerosol

Simultaneously, it was possible to confirm by the micros-
copically, directly determined particle size distribution of the
aerosol for particles of granule size > _ μm that the classical
method (collecting by thermal precipitation of the particles)
corresponded essentially to the photoelectrical method. The cor-
responding particle size distribution is shown in Fig. 2.

On the basis of the recording of the instrument, the
particles can be grouped into 15 granule classes [ranging] from
0.3 to 8 μm.

For the determination of the filter efficiency, the ex-
perimental aerosol is placed into a spherical, air-tight con-
tainer of 700 liter capacity and then drawn through the filters
which are to be tested. Two types of tests were made:

a) The concentration (number of particles per cm^3) is
alternatingly measured for each class of granules, prior to
and after passage of the aerosol through the filter (Fig. 3).
The average of a certain number of subsequent measurements in-

- 3 -

dicates the absolute permeability of a filter which is refer-
red to the correlation between the input concentrations and
the permeating concentrations as a function of the particle
for an aspiration rate of 1 cm/second. Figs. 4 and 5 represent
experimental results for a filter of average efficiency (Fil-
ter No 1) and for a filter of high efficiency (Filter No 2).
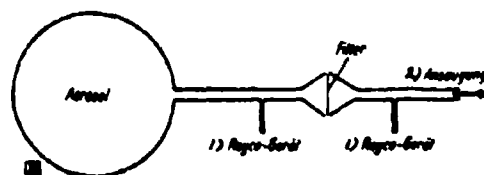The total permeability represents the average of these results.

Fig. 3 Principle of the experimental arrangement for the meas-
urement of the degree of efficiency of a filter.
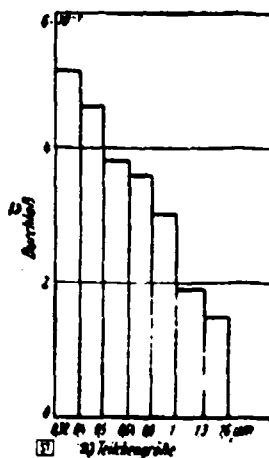1 = Royco instrument; 2 = aspiration

Fig. 4 Permeability of a
filter of average efficien-
cy (Filter No 1) as a func-
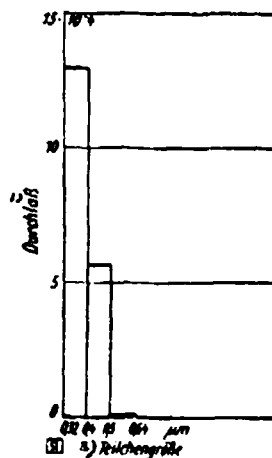tion of particle size.
1 = permeability
2 = particle size

Fig. 5 Permeability of a filter
of high efficiency (Filter No 2)
as a function of particle size.
1 = permeability
2 = particle size

b) For a constant aerosol concentration on the filter,
the concentration permeating through two parallel filters of

known efficiency is compared this indicates the relative permeability of two different filters (Fig. 6). Fig. 7 represents the change in permeability of Filter No 1 as a function of the throughput rate for particles of dimensions between 0.3 and 0.4 µm (upper curve) and for the entire particle size distribution of the aerosol. As is evident, the curves run close to one another and coincide when the aspiration rate surpasses 8 meter/second.
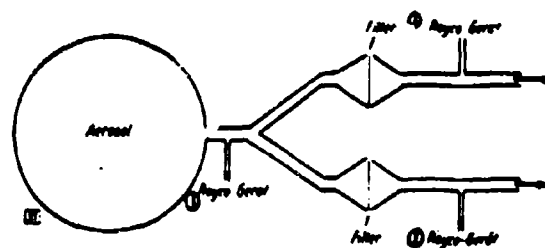

Fig. 6 Principle of the experimental set-up for a comparative determination of the permeability of two filters.
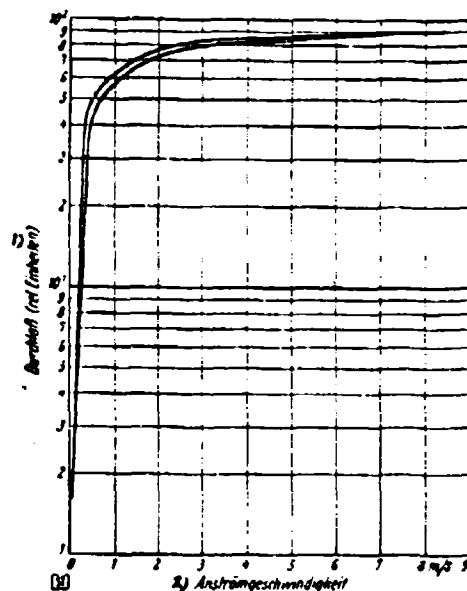1 = Royco instrument

Fig. 7 Permeability of a filter of average efficiency (Filter No. 1) as a function of the input rate (upper curve for particles of 0.3 to 0.4 µm [diameter], lower curve for the entire test aerosol. 1= permeability (relative units); 2=input rate

3. Studies of Volatile Aerosols (3)

The dilution necessary for the above-described measuring device makes it impossible to study volatile aerosols. However, a system has been developed by means of which it is possible to make a direct study of aerosols with concentrations of less than a few thousand particles per cubic centimeter. In this case, the aerosol is directly drawn through the device [and] remains, at the most, for a few one-hundredths of a second within the instrument. After it had been confirmed with an artificial aerosol that the results obtained with this system are in good agreement with particle size determinations of the cascade impactor within the experimental range of the instrument, the following important studies were carried out with this arrangement.

3.1. Composition of Natural Clouds (from the Puy deDome Peak)

Fig. 8 shows the results of this case. the ordinate indicates the number of particles migrating within ten seconds through the light field of the microscope as a function of the
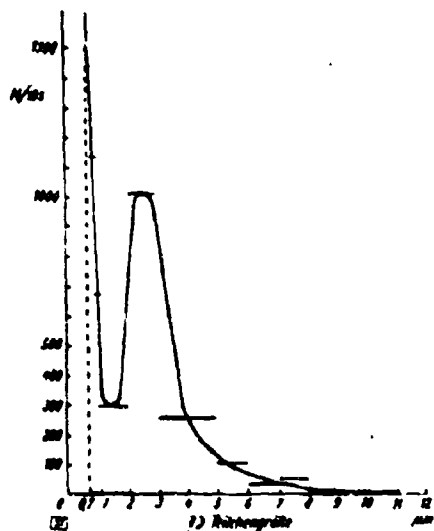

Fig. 8 Particle size distribution of natural clouds.
1 = particle size

diameter indicated on the abscissa. It is seen that within the region of small particle diameter, a maximum is followed by a minimum at approximately 1.5 μm and subsequently again by a steep increase. This result had hitherto not been found with the classical sampling methods (collecting by collision, wire meshes, et cetera).

3.2. Composition of City Fog

When the same experimental method is applied to natural fogs, as they are formed, for instance, in Paris, a particle size distribution similar to that one shown in Fig. 8 is found; however, the maximum is less pronounced [and], at times, it disappears entirely, thereby resulting in a curve with continuously increasing particle number with decreasing particle diameter. It is found that city fog occurs only and is stable only when the air humidity of the surrounding areas is below 100 per cent. This fact may be explained when it is assumed that the atmospheric droplets form at particles produced in combustion processes, which are floating in the air; these particles consist essentially of SO_3.

The following Table shows in [terms of] number of drops per cubic centimeter the particle size distribution of a fog at an atmospheric humidity of 70 per cent.

T/cm^3	1070	16.0	0.746	0.021	0.059	0.076	0.058
diameter (μm)	0.8-2	2-4	4-6	6-8	8-10	10-12	12-14

T/cm^3	0.014	0.006	0.004	0.002
diameter (μm)	14-16	16-18	18-20	20

Since the relative humidity of the air is known at the time the measurement is made, the mass m of the matter dissolved in one particle which is in a state of equilibrium can be calculated. The calculation shows that the amount of SO_3 necessary for the equilibrium is 506 μg/cubic meter. Direct chemical measurements yield a value of 584 μg/cubic meter, that is an amount which is only slightly above the result of our calculation, which is, however, absolutely of the same order of magnitude. The difference is obviously caused by the possible presence of other

substances in the solution, which bring about a lowering of the vapor pressure, and by the presence of smaller droplets (which probably amount to 15 per cent of the total mass of droplets), which cannot be detected.

[English Summary appearing on p. 290 of the original article:]

The principle of a method for evaluation of the particle--size distribution of an aerosol is first described; in this method the scatter-light emitted from each individual particle is measured. As examples of the applicability of the method results are presented for the efficiency of filters and also investigations on the composition of natural clouds and town mist.

Literature References

1. J. Bricard, M. Deloncle, and G. Israel, Ann. Geophys, Vol 15, 1959, page 415.
2. G. Madelaine, Etude du pouvoir d'arret de differents filtres. (Study of the retaining capacity of filters). Contribution presented at the Conservatoire National des Arts et Metiers in fulfillment of the engineering diploma CNAM, 1963.
3. M. Deloncle, Dissertation, Paris, 1963.

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